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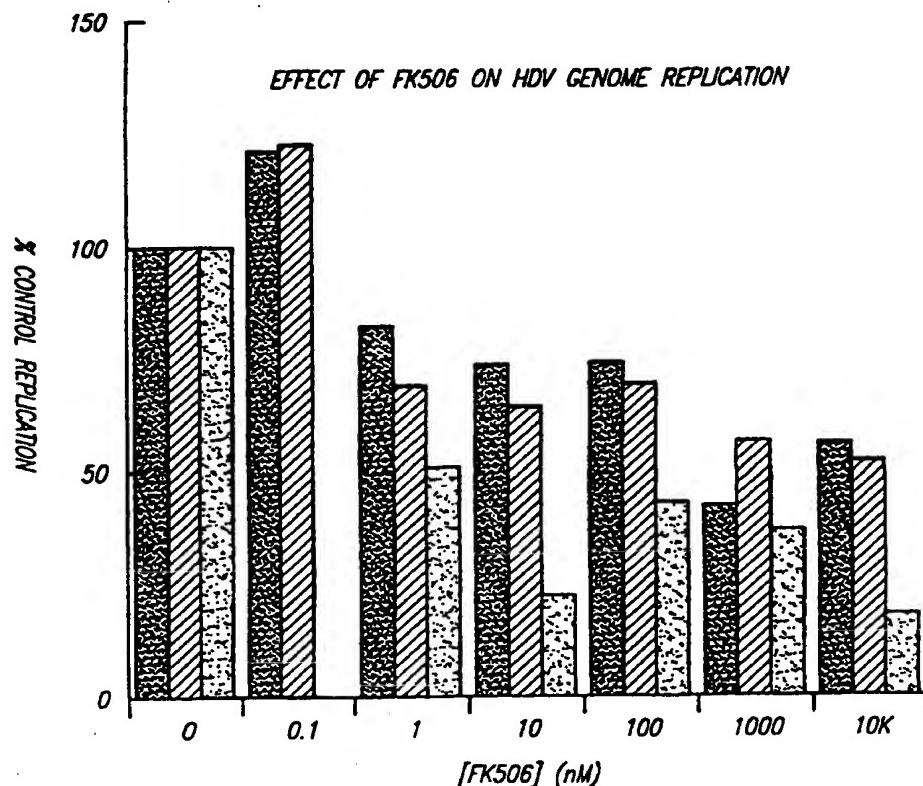
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(54) Title: ANTIVIRAL COMPOUNDS

(57) Abstract

The macrolide FK506, produced by Fujisawa Pharmaceuticals is effective in inhibiting the replication of hepatitis D virus (as shown in the figure). It is believed that replication is inhibited either by virtue of the ability of FK506 to inhibit proline isomerase or otherwise to interfere with the function of a C-terminal proline in a replication factor or by virtue of its interference with RNA replication directly.



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ANTIVIRAL COMPOUNDS

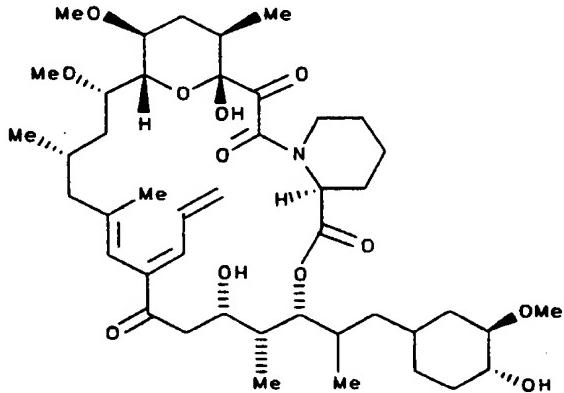
This invention was made with government support under grant no. AI-22470 awarded by the National Institutes of Health. The government has 5 certain rights in this invention.

Technical Field

The invention is directed to inhibitors of viral replication. In particular, it concerns the use of compounds related to the immunosuppressant macrolide 10 FK506 to interfere with replication.

Background Art

The macrolide FK506, which is of the formula:



is manufactured by Fujisawa Pharmaceutical Company Limited, and is a known immunosuppressant. It is a 15 member of class of immunophilins described by Schreiber, S.L. in Science (1991) 251:283-287. Other members of this class include rapamycin, cyclosporin A, and an additional macrolide designated 506BD. However, the present applicant is unaware of any suggestion that 20 FK506, which is also known to be a proline isomerase (or rotamase) inhibitor, or the other compounds described in this article would have antiviral activity. Unexpectedly, FK506 was found to be capable of inhibiting hepatitis Delta virus (HDV) replication.

U.S. Patent 4,196,437 describes the ability of compounds related to FK506 to regenerate liver which has been negatively affected by hepatitis B and non A/non B. However, this appears to be unconnected with 5 any direct effect on the virus.

Disclosure of the Invention

The invention is directed to a method to inhibit viral replication illustrated by the ability of FK506 to inhibit hepatitis D virus replication. The 10 surprising ability of FK506 to do this suggests that replication of a variety of viruses which share features with HDV may be inhibited by compounds related to FK506, provided at least one of several specific conditions is met. FK506 is known to have proline 15 isomerase inhibiting activity. HDV antigen behaves as a transcription factor (defined herein as a protein that plays a key role in nucleic acid polymerization) and contains a C-terminal proline essential for replication, independent of the preceding amino acid 20 sequence. Therefore, the ability of FK506 to inhibit HDV replication suggests that compounds which inhibit proline isomerases or which otherwise interfere with the function of a C-terminal proline in an essential 25 replication factor will inhibit replication of viruses that replicate via at least one such transcription factor.

Accordingly, in one aspect, the invention is directed to a method to inhibit viral replication which method comprises contacting a virus or a cell in which 30 a virus replicates, where the virus contains at least one transcription factor which has a C-terminal proline, with an effective amount of at least one proline isomerase inhibitor such as FK506 or of an inhibitor of proline recognition or function. In 35 another aspect, the invention is directed to a method to inhibit viral replication wherein the virus, like

HDV, replicates through an RNA intermediate, which method comprises contacting the target virus or a cell in which the virus replicates with FK506 or its acyl esters.

5 Brief Description of the Drawings

Figure 1 is a bar graph showing the effect of FK506 on HDV gene replication.

Modes of Carrying Out the Invention

In the illustration below, it is demonstrated
10 that FK506, a proline isomerase inhibitor, is capable of inhibiting HDV genome replication. This surprising result leads to the conclusion that viruses which replicate in a manner similar to HDV will be similarly affected by compounds related to FK506. The features
15 of HDV replication which are significant for interaction with FK506 include replication through an RNA intermediate and/or the presence of an essential transcription factor having a C-terminal proline.

Viruses known to replicate through an RNA intermediate include those belonging to the picornavirus, togavirus, bunyavirus, orthomyxovirus, paramyxovirus, rhabdovirus, retrovirus, arenavirus, and hepatitis B virus families.

Viruses known to contain an essential transcription factor with a C-terminal proline include human adenovirus, feline leukemia virus, vaccinia virus, papilloma virus, hepatitis C virus, hepatitis B virus, human immunodeficiency virus, varicella zoster virus, and bunyavirus.

For any proposed target virus, the ability to ascertain these features is within the skill of the art and provides a basis for concluding or not concluding that the relevant class of antiviral compounds will be effective.

FK506 has the structure set forth in the Background section above. FK506 contains three free hydroxyl groups; each hydroxyl group independently may be esterified with an acyl group of 1-6C. By "acyl (1-6C)" is meant a saturated or unsaturated moiety of the formula RCO wherein R is saturated or unsaturated hydrocarbyl. Typical such acyl groups include acetyl, penten-1-oyl, propanoyl, 2-methyl propanoyl and the like.

Proline isomerase inhibitors other than FK506 include rapamycin, cyclosporin A, 506BD and their acyl derivatives. All of these compounds are useful in the invention.

The following example is intended to illustrate but not to limit the invention.

Example 1

Inhibition of HDV with FK506

HDV gene replication was assayed by the method of Glenn, J.S., et al. J Virol (1991) 65:2357-

2361. FK506 was supplied at various concentrations into the replication assays.

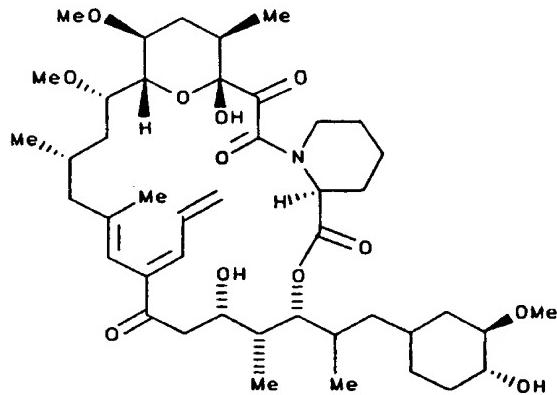
One day post delivery of S-genome RNA to GAG cells, the GAG cells were split equally into 60 mm dishes, which were maintained at specific concentrations of FK506 ranging from 0.1 nM to 10 μ M until harvest on day 7. The harvested RNA was assayed by Northern blot to detect HDV genome replication. The Northern blots include a control probe for host cell RNA (Signal Recognition Particle Receptor mRNA) to permit normalizing total RNA levels. Phosphoimaging analysis permitted sensitive quantitation and comparison of levels of viral replication.

The results of three experiments are shown in Figure 1; each bar reflects the level of HDV genome replication at the indicated drug concentration. The solid and striped columns represent results from duplicate dishes showing the degree of variability. The stippled columns represent results obtained in a previous experiment conducted two months previously when the drug was freshly constituted.

The results show that nM concentrations of FK506 achieve about 50% inhibition of HDV replication.

CLAIMS

1. A method to inhibit the replication of a virus, which virus replicates through an RNA intermediate, which method comprises contacting said 5 virus or a cell in which the virus replicates with a compound of the formula:



or a pharmaceutically acceptable acyl (1-6C) ester thereof effective to inhibit said replication.

2. The method of claim 1 wherein said virus 10 is picornavirus, togavirus, bunyavirus, orthomyxovirus, paramyxovirus, rhabdovirus, retrovirus, arenavirus, hepatitis B virus or hepatitis D virus.

3. The method of claim 1 wherein said virus is hepatitis D.

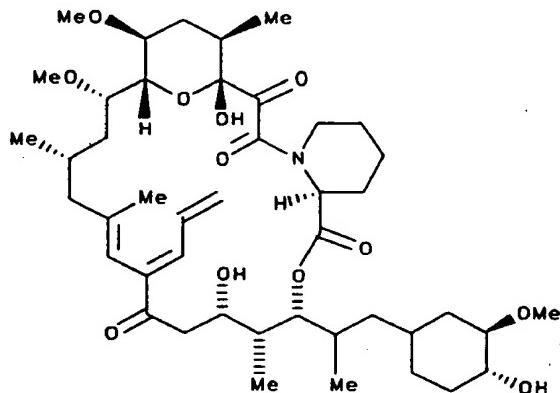
15 4. A method to inhibit the replication of a virus which employs, for regulation of transcription, at least one transcription factor containing a C-terminal proline critical to the function of said transcription factor, which method comprises contacting 20 said virus or a cell in which a virus replicates, where the virus with an amount of a proline isomerase inhibitor or C-terminal proline-dependent binding agent

or proline recognition inhibitor effective to inhibit said replication.

5. The method of claim 4 wherein said virus
is human adenovirus, feline leukemia virus, vaccinia
5 virus, papilloma virus, hepatitis C virus, hepatitis B
virus, human immunodeficiency virus, varicella zoster
virus, bunyavirus or hepatitis D virus.

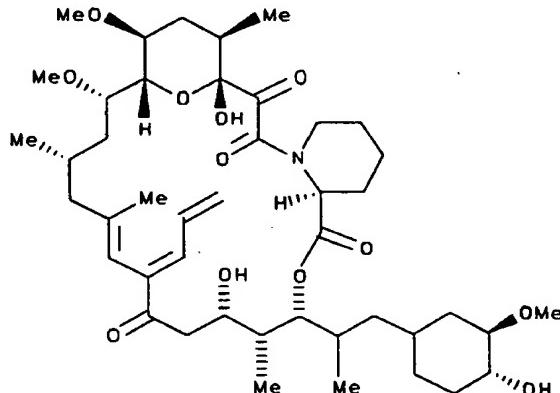
6. The method of claim 4 wherein said virus
is hepatitis D virus.

10 7. The method of claim 4 wherein said
proline isomerase inhibitor is rapamycin,
cyclosporin A, 506BD or is of the formula:



or the pharmaceutically acceptable acyl (1-6C) esters
thereof.

15 8. The method of claim 4 wherein said
proline isomerase inhibitor is of the formula:



or a pharmaceutically acceptable acyl (1-6C) ester thereof.

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FIG. 1

